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ABSTRACT

This final report describes the design, development, and testing of the Multiple Output Sensory Trainer (MOST), a computer-based system which enables the evaluation of students with visual impairments to determine the optimal combination of sensory adaptive aids to meet their needs. The system uses multimedia devices in conjunction with customized software. The MOST system also assists visually impaired students in gaining access to print handouts. The system is portable and can quickly convert printed handouts to either braille or large print. The system can be used to design customized lessons for the student which he/she can then use on a home MOST computer. The report details the rationale behind the selection of the specific MOST hardware (IBM PC-type) and software (Windows operating system). It also explains design of the MOST user interface, the MOST relational database, the design of program linkage, and selection of a scanner to allow print-to-Braille/large print conversion. The system was field tested with four eighth grade students (two blind and two with low vision. Results indicated that all students did best with the high quality speech synthesizer. The low vision students did best with a combination of speech and large print. The totally blind students did not do any better with refreshable braille and speech versus just speech. The use of the 8.5 inch hand-held optical scanner to quickly convert print handouts to braille or large print was very beneficial. The use of the CD-ROM drive on the MOST system was useful to students in performing research. Also, the ability of the itinerant vision teacher to create MOST lessons using the object oriented programming language was very useful. (DB)

Multiple Output Sensory Trainer (MOST)

Final Report

Contract Number: H180C00008

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EXECUTIVE SUMMARY

The Multiple Output Sensory Trainer (MOST) is a computer based system which enables evaluation, training, and provides assistance to visually impaired students. The system uses multi-media devices in conjunction with customized software. The system enables the evaluation of visually impaired students to determine the optimal combination of sensory adaptive aids which meet their needs.

The MOST system also assists visually impaired students in gaining access to print handouts. The system is portable and may be moved to any school. It can quickly convert printed handouts to either braille or large print. This saves the visually impaired student a great deal of time.

An itinerant vision teacher may also design custom lessons to help visually impaired students with specific subjects. The visually impaired student uses these customized lessons on their home MOST computers.

Automated Functions, Inc. (AFI) performed this research project. AFI is very proud of this project and the design and development of the MOST prototype system. They would like to demonstrate the system for the Department of Education. This demonstration would permit the Department of Education staff to try this innovative system.

The MOST architecture was structured so it could be enhanced to aid other disabilities. AFI plans to continue the MOST research to optimize the system for visually impaired students and expand it for other disabilities.

OVERVIEW OF MOST SYSTEM

The MOST project involves the use of many sensory adaptive aids linked to a portable computer. This computer may be carried to different schools in order to evaluate students on the optimal combination of sensory adaptive aids. The system is also used to assist visually impaired students in quickly converting print handouts to braille or large print.

Each visually impaired student in the MOST project was furnished a computer. Their computer was placed in their home and equipped with adaptive aids which best met their needs. The home MOST computers allowed the students to perform MOST lessons and homework.

The itinerant vision teacher uses the MOST portable computer to evaluate students. Each student is tested with different combinations of adaptive aids. The input evaluator tests keyboard skills using a regular and a braille keyboard. The output evaluator tests many different combinations of refreshable braille, synthetic speech, and large print adaptive aids.

The MOST portable computer also enables the itinerant vision teacher to quickly convert printed handouts to either braille or

large print. This is accomplished by the use of a 8.5 inch wide hand-held optical scanner. The teacher pulls the scanner down the printed page and the data is converted to text and stored on the computer's hard disk. This data is then either given to the student on disk, or printed in large print or braille. This fast conversion of printed handouts to braille or large print is a great benefit to the visually impaired students.

The portable MOST system also enables the itinerant vision teacher to design and develop new lessons to assist visually impaired students. The system includes an easy to use visual language which is easy to learn. This easy lesson generation facility enables the itinerant vision teacher to quickly create custom lessons for the visually impaired students. This is helpful for those students who are having problems in certain courses. The visually impaired student takes the lesson home on disk and runs it on their home MOST computer.

The portable MOST computer is also equipped with a CD-ROM drive. This enables the itinerant vision teacher to access CD-ROM based books such as encyclopedias. Information may be extracted from the CD-ROMs and placed on disk. The disk may then be given to the visually impaired student who may read it via their home MOST computer.

The MOST project is based on multi-media peripherals and its wide range of use is multi-dimensional. It serves to evaluate visually impaired students to determine the best combination of sensory adaptive aids. It also enables quick conversion from printed handouts to either braille or large print. Custom lessons may be created to provide extra assistance for the visually impaired students. Its CD-ROM drive permits fast and quick scanning of reference material. The system is portable and can be easily carried to different schools.

The visually impaired student's MOST home computer is also multi-dimensional. It may be used to perform most homework assignments. Term papers may be created, spell checked, and printed. MOST lessons can be run in order to assist the student.

The MOST project created an environment in which custom computer software linked with multi-media devices created an extremely useful system to assist visually impaired students. Its modular software architecture enables MOST to be enhanced in the future to assist other disabilities.

OPERATIONAL PROCEDURES AND FINDINGS

Automated Functions, Inc. (AFI) followed a well formulated plan for the design, development, and testing of the MOST system. The project was divided into five major objectives. Each objective was completed and resulted in a successful MOST prototype system. The objectives are described below.

OBJECTIVE 1 -- SELECT MOST HARDWARE AND SOFTWARE.

The prototype MOST system focuses on the needs of visually impaired students. The system requires a personal computer (PC) which serves as a base for many adaptive aid devices. This PC runs software called an operating system. The design of MOST is modular, so it may be expanded in the future to assist other disabilities.

The AFI researchers created a list of requirements for the MOST system. These requirements were divided into two categories. The mandatory requirements must be satisfied in order to create the system. The desirable requirements added value to the system but were not imperative.

First, a list of possible sensory adaptive aids were compiled. This enabled AFI to determine the scope of hardware peripherals needed by the system. Next, AFI created a list of requirements needed in the PC. Last, an analysis of operating systems was needed in order to select the best one for the project.

AFI surveyed sensory adaptive aids which assist visually impaired people. This list is shown in Table 1.

* Refreshable Braille Display
* Braille Graphics Printer
* Braille Keyboard
* High Quality Speech Synthesizer
* Medium Quality Speech Synthesizer
* Low Quality Speech Synthesizer
* Lowest Price Speech Synthesizer
* Hand-held Optical Scanner
* CD-ROM Drive
* Large Print System

Table 1. Sensory Adaptive Aids For MOST System

A short description of each of the above sensory adaptive aids is presented below. The reason for its use in the MOST system is also provided.

Refreshable Braille Display

A refreshable braille display contains between 20 and 80 braille cells. Software is run on the PC which outputs screen data to the braille display. The visually impaired user reads (feels) the braille which corresponds to data on the visual screen.

The MOST system needs to have total control over all sensory adaptive aids. For example, this enables MOST to place data on the braille display that is not shown on the visual screen. This may be necessary if a student is being evaluated on braille, but can see part of the text on the visual screen.

Braille Graphics Printer

A braille graphics printer creates hard copy braille. The printer may also be placed in "graphics" mode which enables dots to be randomly printed on the line. This feature coupled with software allows raised line drawings for illustrations.

The purpose of a braille printer for the MOST system is to create hard copy braille for the student. The student may perform homework using their home based MOST computer. The homework may then be printed in braille and also in ink print.

In addition, the itinerant vision teacher may take the portable MOST system to a student's school, optically scan a handout, then print it in braille. This creates a quick way for the student to gain access to homework assignments.

Braille Keyboard

A braille keyboard consists of six keys and a space bar. The six keys correspond to the six dots which comprise the braille cell. Multiple keys are depressed to form different letters and numbers.

A braille keyboard is needed by the MOST system to test the braille typing speed and accuracy of the student. A regular keyboard is also used and provides a good comparison.

High Quality Speech Synthesizer

A speech synthesizer converts text to speech. It uses rules of pronunciation in order to have an unlimited speaking vocabulary.

A high quality speech synthesizer sounds very natural. Its limitation is its high price of about $1,600.

Medium Quality Speech Synthesizer

A medium quality speech synthesizer does not sound as natural as the above. Its price is approximately $1,000.

Low Quality Speech Synthesizer

A low quality speech synthesizer does not sound natural. It also mispronounces many words. Its price is about $400.

Lowest Price Speech Synthesizer

The lowest price speech synthesizer sells for about $120. Its speech is not natural and it makes a lot of mispronunciations.

Hand-held Optical Scanner

A hand-held optical scanner is used to scan printed text into the computer. The majority of hand-held scanners are used for desk top publishing.

A hand-held scanner is needed by the MOST system to enable the itinerant to assist the visually impaired student in converting printed text to braille or disk. The majority of hand-held scanners are four inches wide. This is fine for scanning pictures, but is not practical for scanning regular documents. The MOST system uses an 8.5 inch wide hand scanner. This allows the itinerant vision teacher to scan a homework assignment by simply pulling the scanner down the printed page. The information is converted to text and may be printed in braille or heard via a speech synthesizer.

CD-ROM Drive

A CD-ROM drive enables CD-ROM disks to be available to the visually impaired student and the itinerant vision teacher. A CD-ROM disk contains a huge amount of information. For example, one CD-ROM disk contains an entire encyclopedia.

Large Print System

A large print system magnifies the print on the computer display. The user may adjust the magnification from two to 16 times its normal size.

A large print system is needed by MOST to create large characters for low vision students.

Selecting MOST Hardware Peripherals

AFI created a list of mandatory and desirable requirements for each of the above peripherals. Technical information was received on each of the different categories.

This technical information was needed to allow the AFI researchers to write software to individually access each peripheral. The ability of MOST to independently control each adaptive aid allows it to access all combinations of devices. This gives MOST total control over the input and output from each adaptive aid.

Table 2 shows the adaptive aid peripherals for the MOST system.

Refreshable Braille Display	Navigator (Telesensory)
Braille Graphics Printer	Romeo (Enabling Technology)
Braille Keyboard	BrailleMate (Telesensory)
High Quality Speech Synthesizer	DECTalk (Digital Equipment)
Medium Quality Speech Synthesizer	BrailleMate (Telesensory)
Low Quality Speech Synthesizer	Double Talk (RC Systems)
Lowest Price Speech Synthesizer	Echo (Street Electronics)
Hand-held Optical Scanner	Hand Scan (Arkenstone)
CD-ROM Drive	(Sony)
Large Print System	Zoom Text (AI Squared)

Table 2. MOST Sensory Adaptive Aid Hardware

MOST Computer System

A crucial part of the MOST system is the computer which contains the above sensory adaptive aids. The three possible types of computers are desk top, portable, and transportable.

A desk top computer has the advantage of having many internal slots for circuit boards. This type of system enables most of the adaptive aids to reside in the computer. The huge disadvantage is that it cannot be easily moved.

A portable computer has the same amount of memory and processing speeds as a desk top. Its advantage is that it weighs only about six pounds and can easily be carried from school to school. Its disadvantage is that all sensory adaptive aids must be externally connected. This is a large limitation since only three external connectors are available at one time. This forces the itinerant vision teacher to constantly change cables for different configurations. Some sensory adaptive aids only are available on PC cards which cannot be used on this type of computer.

A transportable computer is a combination of the desk top and portable. It weighs about 15 pounds but has four internal slots. The computer has a built-in screen and keyboard. A larger screen may be connected for use by a low vision student.

AFI performed an analysis of all three types of computers. The AFI researchers and the MOST Advisory Committee selected the transportable computer for the itinerant vision teacher.

The next computer selection was for the student's computers. The major criteria was to have a system in which the student could perform homework, print results in print and/or braille, and perform MOST lessons. The computers must also be expandable to permit connection to peripherals such as CD-ROM drives.

The computer which met the student's needs was a desk top system. The best sensory adaptive aids for each computer was not known until each student was evaluated on MOST.

Selection Of An Operating System

The MOST system runs on an IBM PC type computer. MS-DOS and Windows are the two operating systems which run on this type of computer.

Windows is a new system which is totally graphic based. It enables better visual presentations than the traditional character based MS-DOS.

AFI created a list of requirements which needed custom software. This list was analyzed to determine which operating system would best meet the needs of MOST.

AFI has over 20 years of software design and development. It is expert in the use of sensory adaptive aids and user interface

technology. AFI selected the Windows system as the software platform for MOST. It offers superior visual presentation and allows scalable fonts. This is an advantage for designing custom software for low vision students.

Computer technology is also rapidly moving towards a graphical user interface (GUI). Most new software and hardware is designed to work with the new Windows system. This will enable AFI to more easily enhance the MOST system to assist other disabilities.

Result Of Objective 1.

The result of Objective 1 was the selection of the MOST hardware and software. The MOST sensory adaptive aids, itinerant vision teacher's computer, and student's computers were selective. The Windows operating system was chosen as the software platform for MOST.

OBJECTIVE 2 -- CREATE PROTOTYPE MOST SYSTEM.

The concept of having many multi-media adaptive aids connected to one computer is new. The way to utilize these devices in order to evaluate optimal combinations for visually impaired students is also new.

AFI researchers believe it is useful to design and develop a simulation or prototype of a computer system. This type of system helps conceptualize different methods for communicating with the user.

A mandatory requirement for MOST is that all adaptive aids must be totally accessible to the system. AFI designed and developed software which communicated with each of the sensory adaptive aids. This software was structured so the AFI researchers could easily communicate with one or several adaptive aids.

A specification for the MOST system was then structured. This specification was discussed with the itinerant and the MOST Advisory Committee.

The AFI researchers implemented the prototype system by designing and developing software which displayed text screens. The software enabled a programmer to quickly display the screens in any order. The user could select any item from the screen.

This prototype software worked well. It enabled AFI, the itinerant vision teacher, and the MOST Advisory Committee to easily try new concepts with the system.

Result Of Objective 2.

The result of Objective 2 was the design and development of the MOST prototype system. The system was structured so it could be easily changed to allow fast and easy experiments.

OBJECTIVE 3 -- DESIGN OF MOST USER INTERFACE.

An important part of any computer system is the interface with the user. The MOST prototype system developed in Objective 2, enabled AFI to quickly change this interface.

AFI created a list of objectives which must be met in order to create a good user interface. The user interface must be easy and consistent for the itinerant vision teacher, visually impaired students, and for lesson generation.

The prototype MOST system (Objective 2) was used to determine that MOST should have both an input and an output evaluator. The input evaluator would measure the student's typing accuracy using a regular keyboard and a braille keyboard. The output evaluator would measure the student's ability to use refreshable braille, large print, or numerous speech synthesizers.

AFI created a menu structured user interface using the MOST prototype system. This was programmed and was well received.

The above user interface allows the student and the teacher to easily communicate with MOST. Another goal of the system is to allow the itinerant vision teacher to design and develop individual lessons or programs for the visually impaired students.

AFI researchers know that most itinerant vision teachers do not know how to write computer programs. AFI contacted several itinerant vision teachers and determined that most could understand the logical structure of computer software but not the mechanics of writing in a language like Pascal, C, or Basic.

Recently, a new type of computer language called "Object Oriented" programming has been created. This type of language is very visual and allows the teacher to manipulate objects on the screen. The ordering of the objects determine the flow of the program.

AFI surveyed this type of computer software. They selected a language which runs on the Windows operating system and enables it to be coupled with other traditional languages. This is ideal for the MOST system, since the AFI programmers could design many constructs using the C Language and make them accessible through the object oriented language.

Result Of Objective 3.

The result of Objective 3 was the user interface for MOST. The interface included a menu structured environment for the teachers and visually impaired students. An easy to use object oriented language was implemented so the itinerant vision teacher could easily create individual lessons for the visually impaired students.

OBJECTIVE 4 -- DESIGN AND DEVELOP MOST RELATIONAL DATA BASE.

The goal of this objective is to design a database system which stores data on student evaluations and permits the teacher to retrieve results in different formats. The database must be flexible to accommodate all sensory adaptive aids and allow the teacher to ask for many different types of comparisons. The implementation of a hand-held optical scanner to quickly convert printed text to braille or large print is another goal of this objective.

A database is software which stores information. It enables the user or programmer to retrieved previously stored data.

There are many different database management systems. They vary according to speed of retrieval, number of keyed fields, type of query language, and interface to programming languages.

AFI performed an analysis of the amount of data needed for one student evaluation using MOST. This task was performed using the MOST prototype system which was developed in Objective 2.

Several lessons where created on the prototype system. Questions which tested the student's comprehension of different stories were generated.

This simulation enabled AFI to determine the approximate number of fields needed in the data base. Each lesson contained questions and their answers. The amount of time per lesson and per question was also counted. AFI estimated that the maximum number of fields in one database record would be 40.

AFI performed an analysis of data base management systems which ran on Windows. The major considerations were the ability of the software to link with an object oriented language and the C programming language.

A database system usually has a built-in language in which data can be retrieved. The input of data is via input forms which are generated by this language.

The MOST system uses a combination of an object oriented language and the C programming language. The object oriented language allows the itinerant vision teacher to create new lessons. The C programming language enables all communication with the sensory adaptive aids.

AFI performed an analysis of the database systems which ran on Windows. None of the systems permitted linkage to an object oriented language.

The AFI researchers met with the MOST Advisory Committee and the itinerant vision teachers. AFI presented two technical approaches for solving the problem of the MOST database system. These are described below.

* Design Program Linkage With A Data Base System

* Design Custom Database Software

Design Program Linkage With A Data Base System

Windows supports a construct called a Dynamic Linked Library (DLL). This construct enables data to be shared between different tasks.

This approach implements a DLL architecture which shares data between the database system and MOST. The object oriented language and the C programming language must be programmed to communicate with this DLL. In addition, the database system must understand the DLL calling protocol.

The DLL protocol between two Windows tasks is dependent on the cooperating programs. This means the database system must be enhanced to accept this type of interface.

AFI contacted the database vendors and asked about general DLL support. All vendors said they were planning to support a DLL interface, but not until the middle to late 1993. This approach is technically possible, but the project would have to be delayed until the database vendors enhanced their systems.

Design Custom Database Software

The second technical approach was to design a small database system which focused on the MOST data requirements. This approach is not as robust as the above, but is technically feasible.

AFI researchers studied the data requirements for the system. An architecture was designed which simulated the relational database model by storing all fields in flat records. In this way, retrieval programs could be written to compare results.

The second approach was selected for the MOST system. The AFI researchers designed and developed the software using the C programming language.

The use of the custom database software met the needs of the MOST system. It was technically feasible in the grant time frame due to the small number of data fields.

Converting Print To Braille Or Large Print

An important part of the MOST system is the ability for the itinerant vision teacher to quickly and easily translate a printed document to braille or large print.

The MOST system can be easily carried to different schools. A major need by visually impaired students is the ability to gain fast access to print handouts.

AFI researchers surveyed the hand-held optical scanners. The

majority of these scanners are used for desk top publishing applications. The user pulls the unit over a picture and it is stored in the computer. The user then incorporates this image in the document.

Most of the hand-held optical scanners are four inches wide. This is not optimal for scanning regular 8.5" by 11" handouts. AFI located one 8.5 inch wide optical scanner.

The technical manual for the 8.5 inch Mitsubishi scanner was obtained. The unit consists of two parts. The main part is the hand-held optical scanner. The user pulls the scanner down the printed page and the image is stored by the computer.

The second part of the scanner is a base unit. This unit enables the system to automatically scan a printed page. The page is placed on the base unit which pulls it past the scanner. The scanner resides above the base unit and transfers the image to the computer.

The above Mitsubishi optical scanner transfers scanned data to the computer. It does not translate the data to characters. The system only scans dot patterns but does not know how to translate these patterns into characters.

AFI surveyed the Optical Character Recognition (OCR) software. This software converts scanned data to text characters.

AFI selected the Calera Data Systems unit. This system is distributed by Arkenstone and consists of a full size PC board. The hand-held scanner attaches to another board in the computer.

The itinerant vision teacher pulls the scanner down the printed page and the data is stored on the hard disk. The data is then converted to text and stored on another file.

The itinerant vision teacher may elect to use the Grade 2 Braille Translate software to print the handout in Grade 2 braille. The teacher may also print the software in large print on the laser printer.

Result Of Objective 4.

The result of Objective 4 was the design and development of a database system for MOST. The system is customized for MOST and allows for all fields to be compared. An 8.5 inch wide hand-held optical scanner was also implemented in the MOST system. It enables the itinerant vision teacher to quickly scan handouts and convert them to large print or braille.

OBJECTIVE 5 -- FIELD TESTING OF MOST SYSTEM.

The MOST project was field tested by students attending the Fairfax County, Virginia School System. The field test ran for six months. Students were evaluated using the MOST portable computer. Computers equipped with sensory adaptive aids which met each

student's needs were placed in each student's home. These computers were used to perform homework, research papers, and MOST lessons.

The MOST project has a very wide range of uses. The itinerant vision teacher uses the portable MOST computer to evaluate and assist visually impaired students in different schools. The students use their home based MOST systems to perform lessons and homework.

AFI researchers along with feedback from the MOST Advisory Committee and the itinerant vision teacher created the specifications for the MOST portable system. This system is based on a 15 pound computer which has a built-in CD-ROM drive and optical scanner. It also contains connections for a refreshable braille display, braille printer, large print software, and many speech synthesizers.

A major goal of this project is to create a system which assists in finding an optimal combination of sensory adaptive aids to meet each student's needs. The AFI researchers, MOST Advisory Committee, and the itinerant vision teacher analyze the best way to perform student evaluations.

The decision was to use a series of lessons. Each student would read a story on the computer and then answer a series of questions. Each lesson would utilize a different combination of sensory adaptive aids. The computer would keep many statistics on amount of time per question and lesson, and the number of correct answers.

The system was designed so the itinerant vision teacher could easily create new lessons. This flexibility allowed the itinerant vision teacher to make new lessons according to past results.

The evaluation was divided into two major areas. First, the input evaluator measured the student's speed and accuracy on a regular and braille keyboard. Second, the output evaluator measured the student's comprehension on different combinations of adaptive aids.

AFI researchers trained the itinerant vision teacher on the use of the MOST system. The training involved the use of the input and output evaluator. It also included training on how to design and develop new lessons.

Selecting Students

The MOST project is designed to assist visually impaired students. AFI asked the Fairfax County School System to furnish a list of visually impaired students from grade 6 to 12. Each student must have a visual impairment of at least 20/100 vision in both eyes or less to qualify.

AFI received a list of students without names. Each student was represented by a number. The student's grade, eye condition, eye

sight, and computer knowledge was listed.

AFI researchers and the MOST Advisory Committee reviewed the list of students. The list was very diverse with only one or two students in each grade. The eighth grade was the exception having seven possible students. Four of these students were selected as MOST participants. Two students have low vision and two are blind. Each student is motivated and all have similar grades.

Performing Student Evaluation

A set of lessons was created by the AFI researchers and the itinerant vision teacher. The MOST portable system was equipped with the following input and output sensory adaptive aids.

Input Evaluation Adaptive Aids

* Regular Keyboard
* Braille Keyboard

Output Evaluation Adaptive Aids

* Refreshable Braille Display
* High Quality Speech Synthesizer
* Medium Quality Speech Synthesizer
* Low Quality Speech Synthesizer
* Lowest Price Speech Synthesizer
* Large Print System

All testing was performed by the itinerant vision teacher. The tests were performed in the student's school immediately after class. This was a convenient time since a late bus permitted nearly three hours for testing.

The evaluation of the students took nearly three months. They were all tested on all combination of adaptive aids.

A lesson for each adaptive aid combination was used. In this way, each student was measured on the same lesson and same adaptive aid combination. This total testing was performed a total of four times.

The input evaluator tested the student's ability to type on a regular computer keyboard versus a braille keyboard. The output evaluator tested the student's ability to comprehend different text by using combinations of adaptive aids.

The input evaluator had the students listen to a sentence. It then asked the student to type the sentence. MOST stored the input from the keyboard and compared it against the sentence. Each word was counted separately in case a student did not type a word. The accuracy and time to complete each sentence was stored.

The output evaluator tested the students using different lessons. Each lesson contained a story which the student read at their own pace. Questions were then asked to try and determine how much of

the story the student understood. The output evaluator used all combinations of the adaptive aids.

The data from the input and output evaluation was analyze. The input evaluation indicated consistent results between different tests. It indicated the speed and accuracy of each student using the regular keyboard and the braille keyboard.

Three of the students did better using the regular keyboard than the braille keyboard. The fourth student did poorly on the regular keyboard and very well using the braille keyboard. This indicated that the fourth student must be given extra practice using the regular computer keyboard.

The output evaluator stored data on the amount of time used to read each story. The time and accuracy to answer each question was also kept.

The speech only evaluation was not as easy to analyze. There was inconsistent results with the use of different speech synthesizers. All students did best with the highest quality speech synthesizer, but results were not consistent with the other three speech units.

A new set of lessons were created to focus on the evaluation of the three lower quality speech synthesizers. These lessons were divided between common text, technical text, and numeric text.

The theory was that the lower quality speech synthesizers mispronounce many words and testing with these categories may indicate a trend. The students were evaluated on these three speech synthesizers with the new lessons. All did best on the common text lesson. The other test results were similar to the first set of tests.

The speech only tests indicated that all four of the students did best using the highest quality speech unit. The lower three speech synthesizers data indicated different results. Three students did best using the medium quality speech unit, and one did best using the lowest price unit.

Most of the sensory adaptive aid vendors claim that the use of refreshable braille and speech is an optimal combination for a totally blind person to interact with a computer. The MOST analysis indicated that there was no benefit in using braille and speech together.

The AFI researchers believe the above result occurred due to the type of MOST lessons. Each lesson had the user read a story and then answer questions. The AFI researchers believe the combination of braille and speech may be most useful when checking a document for capitalization of letters and checking the exact format of the text. AFI plans, in the future, to create different lessons to try and determine if the above is valid.

The MOST analysis with large print indicated that the two low

vision students did much better using a combination of large print and speech.

Student MOST Computers

The results of the MOST evaluation indicated the best adaptive aids for each student. The highest quality speech synthesizer was not used due to its extremely high price.

Each student received a PC with specific adaptive aids. The adaptive aids were the ones found in the MOST evaluation to best meet the student's needs. The computers were placed in the student's home so they could be easily accessible. AFI researchers trained each student on the use of the computer. They were taught how to run MOST lessons and how to use application programs.

Using The Optical Scanner

Another part of the field test is the use of the hand-held optical scanner. The itinerant vision teacher could take the MOST system to any of the student's schools. The system enabled the student to quickly obtain braille or large print from printed handouts.

This was very beneficial to the visually impaired students. It enabled very fast conversion of handouts from print to braille or large print.

An unexpected advantage of the MOST system was the usefulness of the CD-ROM drive. All four students needed to write a research paper. The itinerant vision teacher used the CD-ROM encyclopedia to extract text and store it on disk. The student then took the disk home and read it using their MOST computer.

This saved the students and the itinerant vision teacher a large amount of time. Each student also created their research paper using their MOST computer. The student's had the computer spell check their research paper, then print it for the sighted teacher.

Creating MOST Lessons For Students

An important aspect of the MOST system is the ability of an itinerant vision teacher to design and develop lessons to assist visually impaired students. The lessons are placed on disk and the student runs the lesson from their home MOST computer. This lesson generation permits the itinerant vision teacher to give extra assistance to the visually impaired student.

The itinerant vision teacher met with the students and their teachers. MOST lessons were created which assisted in geography, science, and math.

The students were given a questionnaire on the usefulness of the MOST system. They thought it was important that the itinerant vision teacher's MOST system be portable. The ability to quickly convert handouts to braille or large print was a great benefit. They thought the evaluations took time, but were not boring. The

MOST home computers were extremely important and enabled both MOST lessons and homework to be performed. The ability to print results for the sighted teacher was a real time saver.

Result Of Objective 5.

The result of Objective 5 was the field testing of the MOST system. The system was field tested by four eighth grade visually impaired students attending the Fairfax County, Virginia School System.

The students were evaluated using the MOST system to determine the optimal combination of adaptive aids for each student. The hand-held optical scanner was used to quickly convert printed handouts to either braille or large print. MOST lessons were also created to provide extra assistance to the students. An unexpected benefit was the usefulness of the CD-ROM drive. It enabled easy access to an encyclopedia which aided in the creation of research papers.

The MOST field test was very successful. The MOST prototype system is currently being used by the school district. The visually impaired students use their home MOST computers on a daily basis.

CONCLUSIONS

The Multiple Output Sensory Trainer (MOST) is a multi-media computer based system which evaluates and assists visually impaired students. The prototype MOST system is portable so it can be easily moved to different schools. The system can be used to evaluate visually impaired students on the best combination of sensory adaptive aids. The itinerant vision teacher may also create lessons which provide extra help. These lessons may be performed by running the MOST software on the student's home computer.

The MOST research project utilized a well formulated approach in the design, development, and testing of the system. The creation of the early MOST prototype system was very beneficial. It enabled AFI to quickly try different interfaces and gain feedback from the end users. This greatly aided in the total structure of the system.

The MOST system is structured in a very modular way. The software is based on the new Microsoft Windows Operating System. The flexible design makes it possible for AFI to enhance the system to serve other disabilities.

The portability of the MOST system was a tremendous asset. It enabled the itinerant vision teacher to visit each student at their school. It would have been extremely difficult to bring the students to one location.

The input and output evaluator worked well in evaluating the students in order to find the best combination of sensory adaptive aids. The easy to use software enabled testing to be performed on

many different combinations of adaptive aids.

The results indicated that all students did best with the high quality speech synthesizer. The low vision students did best with a combination of speech and large print. The totally blind students did not do any better with refreshable braille and speech versus just speech.

The use of the 8.5 inch hand-held optical scanner to quickly convert print handouts to braille or large print was very beneficial. A smaller hand-held optical scanner would not have been as useful due to the regular size of the handouts. It would have forced several scans over the page which would have made the optical character recognition process much more difficult. The ability of the itinerant vision teacher to bring the MOST system to their school and perform this conversion aided all students.

The use of the CD-ROM drive on the MOST system was useful to students in performing research. All students used the encyclopedia on a CD-ROM to assist in the creation of research papers.

The ability of the itinerant vision teacher to create MOST lessons using the object oriented programming language was very useful. This feature enabled the vision teacher to customize lessons for each student in order to provide extra assistance on specific subjects. The students ran these lessons on their home MOST computers.

The concept of having a multi-media portable computer based system which assists visually impaired students is new. This research project designed, developed, and tested a prototype system. Results indicate that a system like MOST can be of significant help to visually impaired students. The architecture of MOST may be enhanced to assist other disabilities.

Automated Functions, Inc. (AFI) thanks the Department of Education for funding this research project. We plan to continue our research on MOST to enhance the evaluation process. We also plan to investigate enhancing MOST to assist other disabilities.